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FUTURE TACTICAL C3 SYSTEMS -
A MULTIPLE CRITERIA DECISION PROBLEM

THESIS

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Per Lt. Col. John M. Halliday, AFIT/LSM

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Presented to the Faculty of the School of Systems and Logistics

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Masters of Science in Logistics Management

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Preface

Over the past decades the capabilities, complexities, and advancements in the fields of communications and computer systems have grown at a rapid rate. The dynamics of this field, which is now generally referred to as "Information Systems" (IS), has created a serious problem to both the military user and the planner.

The vast number of new capabilities and technological advances have made literally every aspect of IS acquisition difficult to say the least. For the most part, the user or using command has allowed these advances in technology to drive their particular requirements, and IS program offices have validated a number of these requirements based on peace-time operations.

The purpose of this thesis was to develop a conceptual and methodological guide by which both users and planners can evaluate and analyze C3 systems to ensure that they will be able to meet the needs of our fighting units in the future. To accomplish this objective, I first of all had to select an operational C3 system upon which to base the analysis. I decided on one of the most complex and dynamic systems operational in the world today - the Tactical Air Control System as it is operated in the Central European Region.

The next step was to develop a methodology that could be used to analyze, evaluate and select future C3 systems. My objective was to develop a technique that would be able to integrate aircraft operations, air vehicle characteristics, and logistics and combat support concepts into the decision-making process. To accomplish this objective, I decided to combine the flexibility of General Systems Theory (GST) with the appropriateness of the "Score Card" multiple criteria problem-solving technique.

The "systems approach" methodology was selected because of its direct application to dynamic and complex problems. Additionally, this methodology was selected because it was to support quantitative and analytical problem solving techniques thus satisfying requirements for empirical rigor.

The "Score Card" problem-solving technique was selected because it allows the analyst to combine the broad scope of the systems approach along with a variable degree of quantitative analysis. In addition, this methodology enables the user to integrate both operational and logistics support concepts into the decision-making process. By using this methodology, the analyst can take advantage of the breadth of the systems approach and the strengths of specific operations research methods.

The degree to which the problem can be solved through either subjective or objective analysis can be directly

controlled by the decision-maker. The resultant decision can also be documented in various degrees of detail dependent on the audience in question. This methodology is ideal for solving complicated C3 systems problems, and it is easily implemented because it combines the best attributes of two of the most widely used problem solving techniques.

I believe the applicability, flexibility and adaptability of this methodology will enable our AF managers and decision-makers to make more effective decisions concerning future C3 systems.

At this time I would like to extend my sincere appreciation to my thesis advisor, Lieutenant Colonel John M. Halliday, for his assistance and patience during my research endeavors. He provided me with the insight, direction and motivation to complete this thesis effort. I would also like to take this opportunity to thank my classmates, Major Roy Smith and Captain David Noble, for their editorial and moral support and to Captain Mark Hinchman for the technical information he provided me over the last few months. Finally, I must extend to my wife, Cheryl, and our four children, my deepest appreciation for their support during this period. The assistance and encouragement of my family and friends will be cherished by me far beyond any of the words written in this document.

Raymond S. Stauffer, Sr.

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Abstract

This thesis describes a conceptual and methodological guide by which managers can evaluate (by comparative analysis) and select future Command and Control, Communications (C3) systems. The general issue is that technological advances have rendered the world of C3 confused and in need of new problem solving methodologies.

The concept is, that in order for future tactical C3 systems to become more effective, they must be integrated with projected operations and support considerations. This integration can best be accomplished by viewing the C3 system in question from a "Systems" perspective. The systems approach identifies the complex interrelationships between C3 systems, the users and the operational context in which the system is to function. The result is a list (score card) of integrated criteria by which future tactical C3 systems can be evaluated.

The methodology discussed combines the flexibility and broad scope of General Systems Theory with the simplicity of the "Score Card" multiple criteria problem-solving technique. Several score card applications are discussed.

Future C3 systems can be analyzed, evaluated and selected by using this conceptual and methodological guide.

FUTURE TACTICAL C3 SYSTEMS -
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I. Introduction

From space-based weapons and warning systems to tactical battlefield reconnaissance, the role of the military's Command, Control, Communications and Intelligence (C3I) function is expanding at an extremely rapid rate. In Fiscal Year (FY) 1985 alone, the Department of Defense (DOD) budget included approximately $36 billion for C3I programs (42:54). This catchall term (C3I) takes in a multitude of communication and information systems capabilities, functions and equipment such as major communications networks, electronic surveillance systems, data processing facilities, software and numerous additional electronic subsystems and components (42:54).

It is widely accepted that future communications systems will assume a magnified importance in times of war or peace; and that the mobility, fluidity, and complexity of future communications systems will reach unprecedented levels (5:v).

According to the Air Force's Principle Deputy Assistant Secretary for Research, Development and Logistics, Mr. Martin F. Chen, we are in the "Golden Age" of C3I with improved technology, very-high speed integrated circuits,

improved visual display units, and higher order computer languages. All of which are being employed to make flying and fighting much more manageable than was ever capable in the past (42:63).

The exploration for technically advanced and more effective C3I systems is constantly being pursued, and breakthroughs are being made at an astonishing rate. Many of our military leaders envision that the numerous projected advances in C3I technology will have direct military applications. As Mr. Chen states:

> We are not far from the time when pilots may literally be presented pictures of recommended flight paths through enemy territories ... The day is near when pilots may change radio channels and bring up desired cockpit displays by voice command. We will see artificial intelligence employed to help the pilot make decisions in the cockpit. (42:63)

General Issue

The Air Force's success in future tactical air wars is most likely to depend on the successful operation of technically advanced and integrated C3I systems. These systems should combine the functions of collecting, processing, analyzing, transmitting, receiving and applying essential information to manage and execute future Air Force (AF) tactical operations in the most efficient and effective manner (9:11).

But will this new and advanced technology be able to assure us that our military forces will be able to meet the

challenges of tomorrow? According to Major General John T. Stihl (HQ USAF/Assistant Chief of Staff, Information Systems) in order to meet future communications challenges the AF must effectively use technology to meet requirements rather than allowing technology to drive requirements. He further states that C3I systems do not have requirements - only users have requirements (40:47).

It is often assumed that emerging technologies will provide the answer to all of the military's communications problems and, that our C3I systems will operate as effectively in wartime as they do during times of peace. This is bluntly and simply not the case (40:46-47). It is my opinion that far too many of our military C3I systems have been validated, funded and purchased based on technological advancements and not on true military necessity.

In reality the main driving force for the introduction of any new communications technology or operational C3I system must be in response to some threat. According to Air Commodore J. Hartog, the main driver of new technology must be in response to a threat assessment assuming countermeasure. He further states that a principle of modern design is to develop C3I systems that are technological, procedural and organizational extensions of the commanders they support (21:51-52).

The goal then of any C3I or information system must be to meet user needs and requirements that have been validat-

ed and substantiated in response to a given threat. This goal can best be accomplished through a comprehensive evaluation and complete understanding of the operational context in which future C3I systems will be utilized, and then only if new C3I systems are integrated with future air vehicle and logistics support concepts.

The key to the success and effectiveness of future C3I systems rests with our current military planners and decision-makers. They must ensure that future C3I systems are integrated with operational and logistics concepts, and they must establish formal and standard procedures by which the effectiveness of our C3 systems can be evaluated.

Specific Problem

In order to efficiently and effectively accomplish the task of planning, programming and fielding C3I systems of the future communications planners, managers and decision-makers must be knowledgeable of user requirements. They must also understand the operational context and support concepts in which C3I systems will be utilized.

The ability of users to successfully identify future requirements, and for C3I planners to implement programs designed to meet these requirements, will determine how successful the AF will be in meeting the communications challenges of the future. One important step in this direction has been the publication of the AF 2000 study, which was released in June 1982 by the late General Jerome F. O'Malley, then the USAF's Vice Chief of Staff.

This study, officially titled "Air Force 2000: Air Power Entering the 21st Century," was initiated to serve as an AF planning guide and to provide a more comprehensive picture of the operational context in which the AF would carry out its missions in the 21st Century (9:1). A key issue discussed in this and other AF 2000 related studies is the future of C3I systems.

Unfortunately, even though most of these studies recognize the importance of future C3I systems and address the tremendous technological advances possible in this area, none of the studies integrate future C3I requirements with their projected operational and support concepts.

To date, an evaluation and integration of C3I systems capable of supporting future tactical air (TACAIR) operations and logistics support concepts has not been accomplished.

Research Objective

The purpose of this research effort is to provide AF planners and decision-makers with a conceptual and methodological guide by which they can establish integrated C3I system selection criteria and make more effective decisions concerning future tactical C3I systems and equipment. The following research questions have been formulated to serve as a guide in this research effort and to provide direction in accomplishing the overall research objective:

1. How can planners identify and integrate future C3I requirements with projected aircraft operations and logistics support concepts?

2. What are the principle characteristics of future TACAIR operations and logistics support concepts and how will they impact future C3I requirements?

3. How can planners and decision-makers make more effective decisions to ensure that future tactical C3I systems will be able to adequately support future TACAIR operations and logistics support plans?

a. By what criteria can planners and decision makers evaluate operational and programmed C3I systems to ensure that their future requirements will be satisfied?

b. What methodology can be used to evaluate C3I systems from an operational and support perspective to ensure that these systems will meet future requirements?

Terms Explained

Before proceeding with any further discussion of C3I systems it must be understood that as a result of the consolidation of the Air Force Communications Command (AFCC) with the Headquarters and Major Commands Data Automation (AD) organizations, the generic term "communications" has been replaced by the term "information systems." This term (Information Systems) is now the generally accepted term used to describe virtually every type of Defense

Communications Agency (DCA) and Department of Defense (DOD) C3I system.

The terminology gets even more complicated when terms such as office automation, management information systems and automated data processing are used during a discussion. Incidentally, the Air Staff is using a new "buzz" word (SC4) to identify both C3 and computer systems. This new acronym (SC4) stands for Systems for Command, Control, Communications and Computers (26).

In this document, however, I have elected to use the acronym "C3," which stands for Command, Control and Communications, in lieu of all other possibilities. For the purpose of consistency, in this document the acronym C3 will be used to generally describe a variety of SC4 capabilities such as voice and data communications , radar, radio, data automation, and other information systems used to assist commanders in the performance of their Command and Control (C2) duties.

Outline of Study

This research effort was conducted in three main phases, and has been written in six chapters. The first chapter provides the reader with information about the general issue, objectives and scope of this research effort.

The next chapter, the "Background," has been designed to establish a basis or common ground from which the analysis of future tactical C3 system requirements can be

focused. The following three chapters correspond directly to the three main phases of this research effort and comprise the findings of this research effort.

In the first phase (Chapter 3) the Tactical Air Control System (TACS), one of the most dynamic and complex of all of the tactical C3 systems, is analyzed and evaluated from a "systems" perspective. In this phase the concepts of General Systems Theory (GST) and the "systems approach" are used to identify the complex processes and interrelationships surrounding tactical C3 systems. The systems approach re-defines the TACS in terms of its inputs, outputs, transformation processes, control and environmental factors.

In the second phase (Chapter 4), future tactical C3 system requirements (criteria) are established and integrated with projected operational and support concepts as depicted in the AF 2000 and other related studies. The end result of analysis is a list of criteria (score cards) by which future C3 systems can be evaluated.

In the third and final phase (Chapter 5), a conceptual and methodological guide for solving multiple criteria problems is presented. In this phase, the "score card" decision-making methodology is discussed and practical application examples are provided.

In conclusion (Chapter 6) I have made some recommendations for further research, and I discuss some of the key issues affecting military planners and programmers as they

attempt to meet the future C3 needs of our operational and support commanders.

Scope of Research

This study concentrates on the organizations, equipment, and procedures that comprise the TACS. The TACS is one of the largest and most complex tactical C3 systems operational in the world today (17). The TACS has been designed to support of tactical flying units anywhere in the world at any time, but for the purpose of this study we will focus on the USAF in Europe (USAFE) TACS as it is deployed in the Central European Region (CER).

The current operational, organizational and procedural concepts employed by the USAFE TACS organizations will serve as the base-line for this analysis. A comprehensive description of the USAFE TACS operational capabilities and organizations has been provided in the following chapter.

Data Collection. The methods used to collect the research data fall into three general categories:

1. Data was obtained from literature reviews of AF 2000 studies to establish specific future tactical air operations and logistics support concepts.

2. Interviews with C3 and tactical experts, along with the research data gathered during Phase I, were used to establish criteria for future tactical C3 systems. Tactical and C3 experts, for the purpose of this research effort, are defined as any USAF officer familiar with the deployment

and operational concepts of the USAFE TACS in the CER.

3. Information concerning the performance characteristics and requirements of currently operational tactical C3 systems was obtained from technical reports and applicable AF planning, programming and source documents.

Limitations. Finally, since this study has been designed to serve principally as a methodological guide, it does NOT contain any classified information. For this reason, many of the specific facts and details concerning operational tactical C3 systems could not be accurately presented in this study. However, sufficient information has been provided to accomplish the research objectives. In addition, intelligence systems have been excluded from further discussions because of the highly technical and sensitive nature of this subject area.

Even with the afore mentioned limitations, each of the issues discussed in this study have a direct and corresponding relationship to virtually all types of C3I systems used in literally every military organization.

II. Background

> Victory smiles upon those who anticipate the changes in the character of war, not upon those who wait to adapt themselves after the changes occur. (10:1)
>
> Air Marshall Giulio Douhet, 1928

The problem of commanding and controlling forces through the use of some sort of communication process is anything but new. Since the "Stone Age" and throughout history, those who failed to consider and use the appropriate organization, procedures and methods to exercise C3 functions and responsibilities found themselves courting disaster. The need to utilize and manage C3 has never been more important than in recent times. Over the past decade or so, the dimensions of C3 have grown exponentially (43:1). Similarly, the terminology, types of equipment and procedures associated with C3 have, also, expanded at an extremely rapid rate over the same time period.

This chapter has been designed to provide planners and functional area managers with a sufficient amount of background information to allow them to fully understand the basic terminology and general concepts associated with USAF tactical air operations and C3 systems as they are employed in the CER. Some of the most commonly used acronyms are defined and the TACS is discussed as it is deployed in the CER.

Terms Defined

The acronyms C2 and C3 have different meanings to different people, and these acronyms appear to be used indiscriminately throughout a vast number of articles published on the topic of military communications (2:31). For this reason, the following definitions have been provided in an attempt to clarify and make some distinction between these frequently confused terms:

Throughout this study, C2 will be defined as:

> The exercise of authority and direction by properly designated commander over assigned forces in the accomplishment of the mission. Command and Control functions are performed through an arrangement of personnel, equipment communications, facilities, and procedures which are employed by a commander in planning, directing, coordinating, and controlling forces and operations in the accomplishment of the mission. (36:3)

Command, Control and Communications (C3) systems then can be defined as a subset of C2 that supplies the organizations, procedures, and equipment by which the designated commander implements C2 decisions or is provided information relevant to the C2 decision-making process.

According to Martin Van Creveld, as stated in his book "Command in War," one of the most useful methods for classifying the means of executing C2 is to evaluate them in terms of the following three general categories; organizations, procedures, and technical means (43:9-10). Each of these general categories will be discussed during the "systems"

phase; however, this research effort will concentrate on the technical means. With this in mind, the remaining discussions of C3 will primarily focus on the equipment.

The technical means or equipment by which commanders accomplish their C2 responsibilities have been categorized by a qualified team of experts on C3 (see reference 2) according to major function or purpose. This study will concentrate on major systems or end items of equipment that fall into one or more of the following categories (2:31):

1) Sensors (Fixed or Mobile, to include radar units).
2) Communications Links (Primarily radios in the tactical environment).
3) Computers and Display Units (including software, hardware, and other decision aids).
4) Weapons platforms and weapons systems.

Typically, a C3 system can be as simple as a pair of two-way hand-held radios or as complex as the world-wide military telephone network. This study will concentrate on one of the most complex C3 systems employed in the AF today - the Tactical Air Control System (TACS).

The Mission of the TACS

The Tactical Air Control System (TACS) is an Air Force (AF) tactical communication and information system comprised of highly mobile, flexible and specialized personnel and equipment designed to meet the unique information gathering, distribution and processing requirements of tactical air operations anywhere in the world at any time (25:3-3 to 3-10).

The purpose of the TACS is to provide the tactical AF commander with a C3 system tailored to meet the unique operational and environmental requirements under which the tactical elements have been deployed. The TACS is comprised of people, organizations, facilities, hardware, software, and procedures by which the Tactical Air (TACAIR) Commander can plan, direct, and control TACAIR operations and interface with other agencies. (25:3-5 to 3-7; 2:2; 21:3).

Within the CER of NATO, the primary mission of the TACS is to: 1) provide a back-up air defense C3 system for the fixed facilities in the NATO Air Defense Ground Environment (NADGE), 2) provide forward area surveillance and reporting to the NATO air defense sector commanders and, 3) serve as the primary air control and warning system should any of the fixed radar facilities falter or be destroyed (28:17).

The specific mission of the TACS in the CER does not differ substantially from the general TACS mission, however the C2 structures and the deployment schemes have been modified to meet the unique military characteristics found in this area.

The NATO Command Structure

During peacetime, all U.S. Forces in NATO are assigned to the U.S. European Command (EUCOM) and all USAF personnel are under the command of the EUCOM air element, the U.S. Air Forces in Europe (USAFE) (41:112-113).

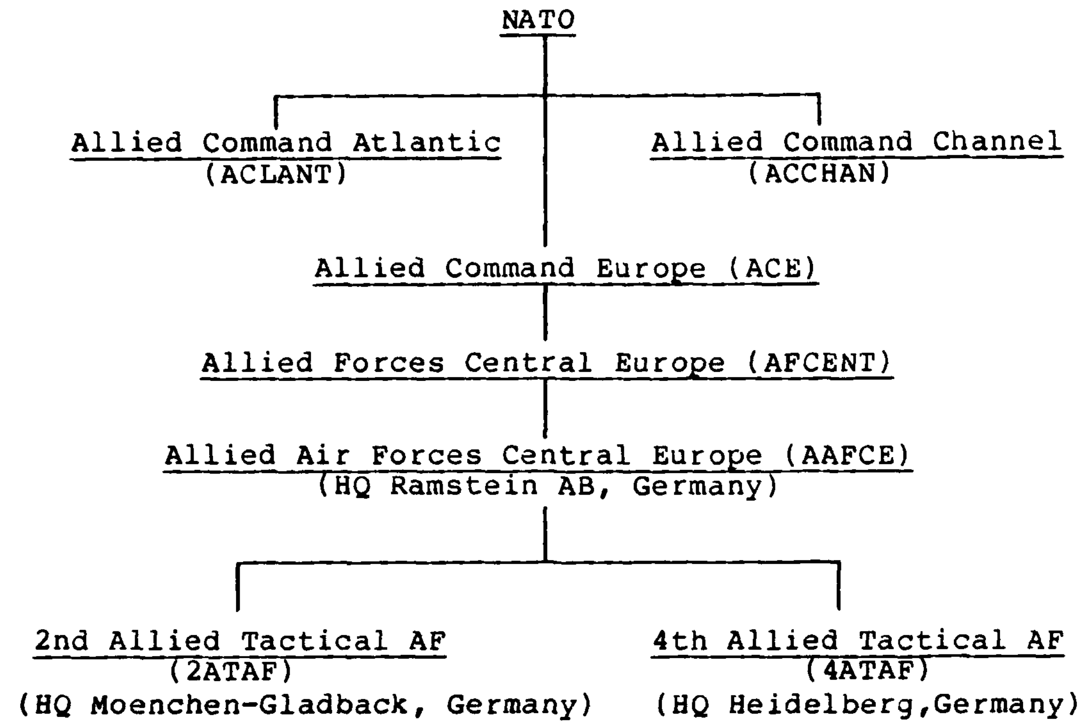

Figure 1.
The NATO Command Structure

However during war, contingency or exercise conditions all NATO operational forces come under the command and control of Allied Command Europe (ACE). All NATO Air Forces in the CER are commanded by the Allied Air Forces Central Europe (AAFCE) Commander as shown in Figure 1 above.

Subordinate to the AAFCE are two Numbered Air Forces (NAF) - the 4th and 2nd Allied Tactical Air Forces (ATAF). Below the NAF level are a number of typical AF subordinate level units such as wings, squadrons and flights (17).

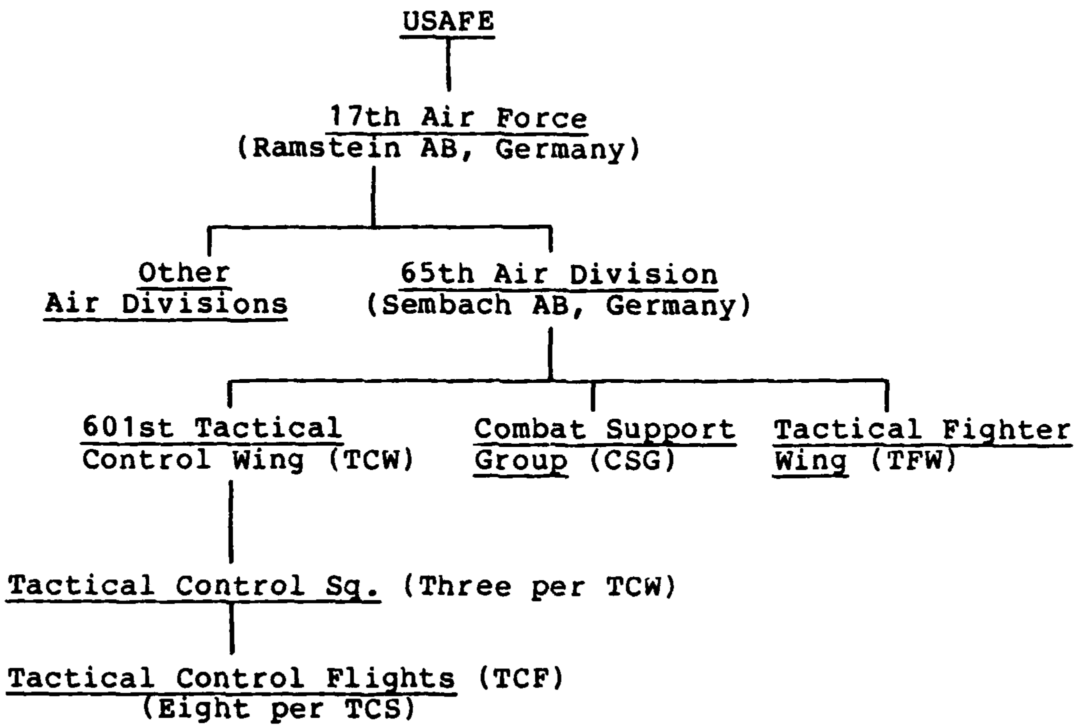

Figure 2.
TACS Organizations in the CER

At this time it is important to point out that many of the key positions in EUCOM and USAFE are dual-hatted. For example, the Supreme Allied Commander in Europe (SACEUR) and the Commander in Chief European Command (CINCEURCOM) are the same person, as is the CINCUSAFE and CINCAAFCE. (41:112,17)

TACS Organizations in the CER

In the CER, TACS equipment and personnel are formed into Tactical Control Wings (TCW), Squadrons (TCS), and Flights (TCF) as shown in Figure 2 above (26).

Elements of these units are pre-positioned in a number of strategic locations throughout the CER. (28:12) During peace-time operations these organizations are responsible to their respective TCW; however, during contingencies or war-time conditions all of the TACS organizations are responsible to the designated commander of the operational unit they have been assigned to support (17; 26).

The TACS units are extremely mobile and can be dispersed to a vast number of operating locations. During wartime conditions or exercises, certain TACS elements are dispersed to an additional number of pre-planned strategic locations and are re-organized to form a network of linking communications, radar sensor, and information processing stations. Once the elements have established their individual linking communications they form an integrated C3 system that covers the entire CER. (38; 28:12-15)

Functions of the TACS Elements

The highest operational elements in the CER TACS are the Allied Tactical Operations Centers (ATOCs) and the Sector Operations Centers (SOCs). The ATOCs are primarily responsible for offensive air operations, while the SOCs control the defensive air operations. The subordinate elements to the ATOCs are the Air Support Operations Center (ASOC), the Tactical Air Control Parties (TACP) and the Forward Air Controllers (FAC). Similarly, each SOC also has two subordinate units - the Control and Reporting Centers

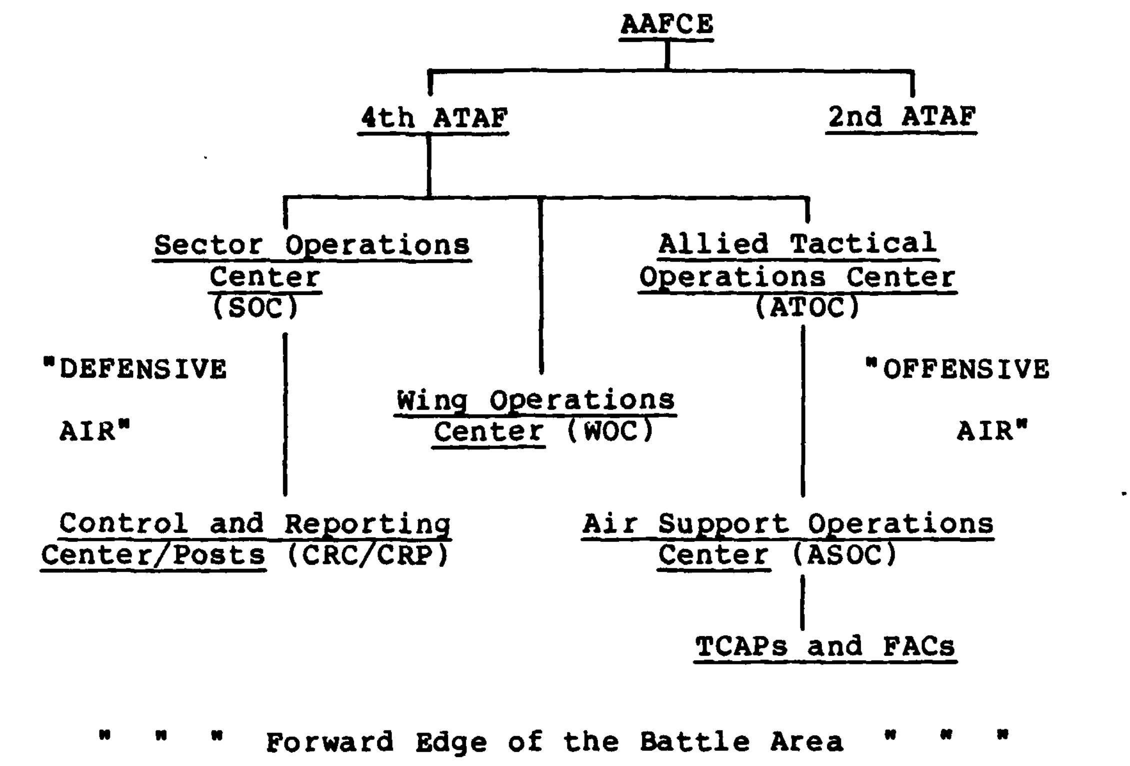

Figure 3.
The Major TACS Elements

and, the Control and Reporting Posts (CRCs/CRPs). (15:2-7; 46:623)

A separate organization that works very closely with the ATOCs and SOCs are the Wing Operations Centers (WOC). The WOCs are not considered as being components of the TACS, but they do receive a majority of their C2 directives through the TACS. (46:622-623) The major operational elements of the TACS are as shown in Figure 3 above (15:2; 17).

The important thing to remember is that the ATOCs and SOCs function as the "command" elements, while their subordinate organizations serve as the "control" structures within this system. Another way of looking at the TACS structure is that the ATOCs and SOCs provide the centralized control elements, and the other elements accomplish the decentralized execution functions.

Tactical Flying Units

During wartime conditions (real or exercise), control of the flying organizations is aligned under the AAFCE, ATAF, and WOCs. These command headquarters are usually located relatively close to a Main Operating Base (MOB). The flying squadrons, however, can either be retained at the MOB, or they can be dispersed to either a Collocated Operating Base (COB) or to a Forward Operating Location (FOL) depending on the aircraft type and designated mission (17; 27).

In order to appreciate the magnitude of these organizations, a typical Tactical Fighter Wing (TFW) consists of approximately 72 fighter aircraft, three Tactical Fighter Squadrons (TFS) and over 4500 operations, maintenance and support personnel (19:24-38).

The C3 systems employed to support these flying elements consists of everything from major Defense Communications Agency (DCA) systems; like AUTOVON, AUTODIN and numerous other tactical systems found at the MOBs, to the

bare minimum C3 capabilities provided to the flying units assigned to the COBs and FOLs (26).

Minimum essential C3 capabilities designated for each tactical flying organization include the capability to access the two major common-user C3 systems (AUTODIN and AUTOVON) and, in addition, these units are equipped with both Ultra High Frequency (UHF) and High Frequency (HF) tactical radios.

Even though the C3 systems located at the COBs and FOLs can access the TACS, they are not considered as being part of the TACS. The C3 capabilities allocated to these organizations are authorized in support of the individual flying organization's Operations Plans (OPLANs) and deployment directives (26).

Organizational Responsibilities

The AAFCE. The AAFCE commander is responsible for the apportionment and allotment of the air forces assigned to the CER. The AAFCE determines the percentage of sorties allocated to each of the three major mission categories, which are: 1) Close Air Support, 2) Air Interdiction, and 3) Defensive Counter Air. These allocations are then sent through the ATAF to the ATOCs and SOCs, where the actual flying unit tasking orders (FRAG Orders) are developed and transmitted to the specific WOCs (8:622).

The ATAF. The ATAFs have operational control over all elements of the TACS and other organizations deployed within

their assigned area. They are equivalent to a U. S. Numbered Air Force and function as a Staff Office during peace-time, and are responsible for controlling all air operations during contingencies and higher level conflicts. (28:11)

The ATOCs and SOCs. These agencies are subordinate to the ATAF and perform the majority of the planning, controlling and directing of the air war effort. The ATOCs are considered to be primarily responsible for the offensive air operations since they pre-plan the number and types of sorties to be flown against enemy targets (46:622). The SOCs, on the other hand, are designated as having control over the defensive air operations because they are the agency primarily responsible for Close Air Support (CAS) operations. Both organizations task their subordinate flying wings to fly specified sorties and retain C2 over these forces through the TACS. (17)

The CRPs. These are large mobile radar units that direct and control the air defense and airspace control operations over a designated area using computer-aided equipment. These units provide identification, navigation assistance, air-to-air refueling and threat warning information to friendly aircraft. It also detects enemy aircraft and assigns their interception to either the Army Air Defense System or the TACAIR interceptors. The CRP can control the intercept of enemy aircraft if required. (28:10)

The FACP. These are small, highly mobile radar units that are deployed close enough to the Forward Edge of the Battle Area (FEBA) to extend radar coverage over the battle area. In addition, they perform all of the services of the CRPs except for aircraft identification. These units do not have computer-aided equipment and must voice-tell (call on a telephone or radio) all flight and situational data into the CRPs for insertion into the computerized TACS (28:10-11).

Other Organizations. In order to simplify this inherently complex and complicated system, the roles of the Airborne Warning and Control System (AWACS), the Federal Republic of Germany's ground based air defense systems, other services and countries tactical C3 interface systems and local base air traffic control systems have been excluded from this analysis. It should be mentioned that the TACS system can access or be accessed by any and all of these systems. In fact the AWACS plays a very important role in the TACS system, but is not considered a formal component of the system because of its numerous other priority missions (34:62-63).

The purpose of the previous discussions has not been to comprehensively describe the operational organizations and technical procedures of TACS, but were presented in an effort to define the "system" under study and to identify the interrelationships between the TACS and its environment. The operation of the TACS in the CER is far too complex and

dynamic to be comprehensively discussed in any type or form of an unclassified document. It is import, however, to understand the basic organizations and the procedural complexities in order to properly evaluate the capabilities, appropriateness and effectiveness of the tactical C3 systems deployed in this region.

TACS Technical Equipment

The following TACS equipment are commonly used throughout the CER and are maintained and transported by personnel assigned to the TACS units (28:16-17; 26):

1. Sensors/Radar Units (CRP/FACP): TPS-43E - A three dimensional radar that gives the altitude, bearing, friend or foe identification, and range of an aircraft or airborne object that is within approximately 200 nautical miles and is within the radar's line-of-sight.

2. Communications Links:

a. TRC-87 (CRP) - A mobile communications van that houses four single channel and one multi-channel ultra high frequency (UHF) radio, used primarily for air-to-ground communications.

b. TRC-97 (ASOC/CRP/FACP) - A mobile communications van that houses UHF radios used for establishing 24 channels over a microwave link between TACS elements and other C2 centers.

c. TSC-53 (FACP) - A mobile communications van that houses UHF and HF radios, a tactical telephone switchboard and one full-duplex teletype circuit.

d. TTC-30 (ATOC/ASOC/CRP) - A mobile communications van that contains an automated tactical telephone switching center capable of handling 300 subscribers. Telephone links are established with other agencies via HF radios.

e. TGC-28 (CRP) - A mobile communications van that houses five secure (encrypted) full-duplex teletype circuits used for the transmission and reception of classified information.

3. Computers and Display Equipment (ATOC/SOC/CRP/CRC): The Siemens 7.760 central processing unit is one of the major computer systems used in the NATO TACS. This system is referred to as the EIFEL-1 (EIFEL is the German acronym for Electronic Information Command System for the Luftwaffe), which is a data processing facility with multiple remote computer terminals and computer-to-computer interfaces. (13:3, 34:67)

4. Weapons Platforms/Systems: All tactical fighter aircraft currently in operation in the CER will be considered in this area; but, for analysis purposes, only certain characteristics of these aircraft will be evaluated. In particular, such characteristics as basing modes, support requirements, and takeoff and landing restrictions will be

discussed and evaluated as these characteristics will have a significant affect on future C3 systems requirements.

TACS Procedures

Within the CER TACS, the procedures and guiding directives have been well rehearsed and thoroughly exercised. In most instances these procedures have been well documented and are written in a number of Operations Plans and Orders used by a variety of nations in the region. The TACS procedures in the CER will not be discussed in any further depth because of the classified nature of this subject matter.

The Problem

Over the past few years commanders have been lead to believe that they will be able to sustain war-time communications similar to those utilized during their daily activities. This simply will not be the case. (40:46) As a matter of fact, virtually every post-exercise report comments on some sort of C3 problem that could seriously affect the ability of the unit in question to perform its mission.

Even the Granada invasion was hampered by C3 problems and there was little enemy effort to disrupt any of the C3 systems employed in support of that mission. (29:60) Imagine the difficulties C3 systems will experience during a sustained major confrontation with the Warsaw Pact.

Because of the vast complexities surrounding the tactical C3 area, using the "systems" approach to identify future C3 requirements is appropriate to say the least.

III. The Tactical C3 System

> The beauty of a system lies not in its technical sophistication or cleverness of implementation but in what it will do for the user. (47:A)
>
> Major General Doyle E. Larson, 1981

The "Systems Approach" problem solving methodology is characterized by the problem-solver viewing the system as a whole rather than concentrating on the individual parts (44:1-2). The ability of this approach to analyze and solve complex problems has been widely accepted and used over the last few decades. Many "systems" theorists believe that this is the most appropiate approach to take when attempting to solve or understand complex problems charaterized by numerous interrelationships set in dynamic environments (44:3-10).

It is my opinion that, unless those personnel assigned the responsibility of planning, programming and selecting future C3 systems at least consider the vast complexities, numerous interrelations and dynamics of tactical C3 systems, we are destined to continue to battle the same problems that have plagued our C3 systems in the past.

By using the systems approach to solve complicated C3 problems, our future C3 systems will be integrated with and better able to support both the operational concept and overall mission requirements.

This chapter discusses the properties of General Systems Theory (GST), and defines the TACS from a "Systems" perspective. In addition, a visual model of the TACS system is presented at the end of the chapter.

General Systems Theory

The application of the GST problem-solving methodology implies some form of departure from the traditional, rational and analytical methods that have been used so successfully over the years on relatively simple problems. The vastly more complex problems of modern-day projects makes it impossible to look for isolated solutions to many of the problems encountered by today's managers and decision-makers. (35:9)

Systems thinking does not do away with analytical thinking - it supplements it. Instead of micro-analyzing the parts, in this case specific pieces of C3 equipment or capabilities, systems analysts focus on the processes that link all of the parts together. (35:6-7) In terms of the tactical C3 system, analysts would consider not only the C3 equipment, but also the operational forces that use the systems along with all of the other sub-elements that have an impact on the C3 system in question.

By using the systems approach, managers and decision-makers are forced to consider and analyze the problem from a much broader perspective. For example, each of the following five basic considerations concerning systems thinking

would be analyzed and evaluated by the decision-maker (35:8-9):

1. Objectives of the total system.
2. The system's environment.
3. Resources of the system.
4. Components of the system.
5. The management of the system.

This is not an all-inclusive list of systems considerations, but from a cursory view of this list one can understand the fundamental concepts of the systems approach. This methodology focuses on the goals, resources, components, management and the environment which is under study or consideration. The ten properties of General Systems Theory (GST) will further clarify these concepts.

Properties of GST

In order to constitute a system there are certain properties that must be evident. Such as:

Interdependence. This is the interrelationship and interdependence of objects and their attributes. Unrelated and independent elements can never constitute a system (35:38).

In the CER, the TACS has numerous interrelationships and interdependencies among its subsystems and the environment. For example, it must be able to access and be accessed by hundreds of different users. The TACS provides information to and from pilots flying in the area, it is dependent on inputs from its radar sensors, and it is con-

trolled by operational requirements. The TACS can be viewed as a system in itself or it can be considered a subsystem of a much larger system like the Defense Communications System (DCS).

Holism. The system is not a reconstituted (resynthesized) one; it is an undivided one - never having to be broken down to be analyzed or evaluated (35:37). Simply stated, holism means that the system in question can be analyzed without having to be broken down into subsystems.

The TACS in the CER is definitely an entity in itself. The system has been modified and uniquely adapted to meet the C3 needs of the military organizations in the region. Even though there are numerous interrelationships between the TACS and other C3 systems, the TACS in Europe is holistic in that it has a definite beginning and end, specified procedures and clearly defined organizational structures. It, also, has very distinctive boundaries - boundaries that clearly show the demarkation points into and out of the system.

Goal Seeking. All systems interact, and this interaction results in some goal or final state being reached or some equilibrium point being approached (35:37).

The goal of virtually every C3 system is to provide the commanding officer and subordinate units with the ability to continuously communicate, process data into information, and

facilitate the war effort in any way possible. The TACS has these same goals and objectives.

Inputs and Outputs. All systems are dependent on some inputs that, when transformed into outputs, will enable the system to reach its ultimate goal. All systems produce some outputs needed by other systems (35:38).

Within the TACS there are numerous inputs into the subsystems and an equal, if not greater, number of outputs. Each of these attributes of the TACS are discussed in greater detail later in this section.

A Transformation Process. All systems, if they are to obtain a goal, must transform some inputs to outputs; i.e., some form of conversion process must take place (35:38).

The process of communication can be as simple as the transfer of an idea from one human to another, or it can be as complex as orchestrating and controlling a major battle plan. The TACS is a media by which data and information is transferred between the operational and support organizations in the CER. Transformations can be accomplished in a variety of ways dependent on the situation and organizations involved. Some of the individual transformation processes are further explained later in this section.

Entropy. Entropy denotes the availability of the thermal energy of a system for doing useful work, i.e., the more available the energy the less the entropy and visa versa (35:38).

The TACS can be viewed as a living organism that acts very similar to the nervous system in the human body. It has some vital components that, if they were lost, could severely hamper the systems ability to function. On the other hand, there are a number of elements that, even though they contribute to the overall capability of the system, if they were to be destroyed very little degradation would result. The brain of the TACS in the CER is the ATOC, and its two subordinate elements the ASOC and SOC.

Regulation. If a system is to interrelate and be interdependent, then the interacting objects must be regulated in some fashion so that the system's objectives can ultimately be realized (35:39).

Within the TACS there are a number of regulations, manuals, and plans that have been thoroughly coordinated and put into practice. Since the success of the TACS is totally dependent on the coordinated effort of each of its components, each of the rules, plans and regulations have been thoroughly exercised and evaluated. The TACS "regulations" will not be discussed in detail because of their classification.

Hierarchy. The systems are generally complex wholes made up of smaller subsystems, and the nesting of systems within other systems is what is implied by hierarchy (35:39).

The hierarchical structure of the TACS is evident by the organizational charts presented in the preceding chapter. This hierarchical structure is designed to provide for the efficient and effective C2 within the system and it also establishes clear lines of authority and communication flow. Each element has a well established chain-of-command and is cognizant of the C2 hierarchical relationships between each of the organizations and key positions.

Differentiation. In complex systems, specialized units perform specialized functions and this differentiation of functions by components is characteristic of all systems (35:39).

The differentiation of the sub-elements of the TACS is evidenced by the specialized missions each are tasked to perform. For example the mission of the CRPs is considerably different from that of the FACPs. There is, however, a high degree of redundant capability between a number of the TACS elements, but the primary mission of each element is clearly differentiated and unique in many ways.

Equifinality. This simply means that open systems, as opposed to closed systems, have equally valid ways to reach the same objective (35:39).

The objective in the TACS is effective and sustained C3 capabilities in the CER during periods of intense engagement with the enemy. To this end, there most definitely are a number of ways by which the TACS can accomplish this goal.

The numerous possible variations and redundancies that have been built into the TACS make it one of the most dynamic and complex C3 systems in the world. This complexity is one of the main reasons for this research effort and is also the driving force behind the need for analyzing the system from a systems perspective.

Summary. The TACS is a complicated system comprised of a number of subsystems that are closely interrelated. The primary subsystems include the technical means (equipment), the organizations (TCWs) and the procedures (regulations and OPLANs) - all of these elements are required to ensure that the TACS performs its mission properly. In addition, these subsystems are strongly influenced by the numerous environmental factors that strongly impact the military in this region. To consider any additions, deletions or changes to this system without considering the possible implications from a systems perspective could be disastrous.

The Tactical C3 "System"

The complexities and dynamics of the tactical C3 arena in the CER presents both planners and decision-makers with a most difficult task. By understanding the complex inter-relationships between the systems and subsystems; and, by understanding the environmental impacts on these systems, planners will be able to make more effective decisions reguarding future C3 requirements.

The TACS can easily be broken down into the basic subsystems or functions associated with a systems analysis. These subsystems are; 1) Inputs into the system, 2) Transformations (conversions that take place within the system), 3) Outputs of the system, 4) Control and/or feedback mechanism, and 5) Environmental factors that effect or influence the system. (35:12-15)

The following paragraphs define the TACS in terms of its subsystems.

The Tactical C3 Subsystems

Inputs. The inputs to the TACS C3 system are as dynamic and complex as the system itself. Inputs come from a variety of sources, such as command decisions, enemy activities spotted by either airborne or ground forces, internally generated data from simulation models or other analytical techniques. Other inputs come from advanced technology or new C3 capabilities, or new requirements that must be satisfied to meet the "threat" or newly defined mission taskings. In addition, there are a number of other highly complex factors (inputs) that come from the environment. Both the subsystem and environmental factors will be further discussed later in this section.

The Process. The process or transformation of C3 within the TACS in the CER consists of a number of technical, organizational, and procedural components each of which is integrated to allow for the effective transfer of

information or command decisions between organizations and operating units. The process is accomplished, however, in many ways such as transmitting, receiving, storing, processing and displaying data and information (26).

For example, in one situation a voice transmission may be converted to an electrical mode like radio waves or a digital signal to be transmitted over telephone lines, and at other times the input may be a digital signal to be analyzed, displayed or simply stored to be used later. In any case, the process of transforming (transmitting, receiving or converting) C2 data and information within the TACS is as varied as there are techniques available. The individual transformation processes will not be discussed because this area is better suited for a more technical and quantitative analysis.

Outputs. The outputs of the TACS can be simply classified as information, but this information can take on a variety of forms. For example, the output could be a hard page copy of an Air Tasking Order, or it could be as simple as a voice telephone call. Outputs of the TACS in the CER can take any of the following forms: 1) Voice communications (clear or encrypted), 2) Digital or analog data to include hard page copies, 3) Computer outputs such as video displays or analysis reports, 4) Inter- or intra-theater transfers and conversions, 5) Error and fault detection messages.

The Control and Feedback Mechanism. The "control" function within a system is sometimes referred to as the feedback loop or cybernetic subsystem, and it is characterized by the following basic elements: 1) A control object, 2) A detector or scanning capability, 3) A comparator or evaluator, and 4) An effector or action-taking function (35:103). The purpose of the control function is to keep the system on course and to detect variances from the norm at the earliest possible point in the process. Once the deviations are detected, corrective measures are initiated before the system fails to accomplish its primary objective.

Within the TACS, this function is accomplished by a number of specialized fault detection circuits that have been built into the equipment and by a few monitor facilities designed specifically to control the system's operation. In addition, elaborate trouble reporting procedures have been established to allow the user to immediately report any and all malfunctions in the system's operations on a real-time basis (26).

The TACS Environment in the CER. The concept of environmental influences on all open systems is commonly accepted, but many authors tend to be too subjective in their definitions. For the purpose of this study it is only important to realize that the environment is, simply stated, a variable in the process that is not directly under the control of the decision-maker (35:179-181). For

example, members of NATO can control the types of equipment to be used in the TACS, but they can not control the propagation characteristics of HF radio signals nor can they be assured that the enemy will not destroy any of the vital TACS units or capabilities.

The ability of the TACS and many other C3 systems in the CER to successfully perform their assigned missions is constantly being threaten by numerous environmental factors such as the Warsaw Pact Nations, DOD budget constraints, local and foreign politics, and a number of other economic, demographic and social factors. The cummulative effects of all of these environmental factors on the TACS over the next few decades would be difficult to determine at this time.

However, environmental factors such as tactical air vehicle characteristics, basing modes, logistics and combat support concepts can be evaluated based on the AF 2000 and other related studies. In addition, projections for new and advanced technology can be considered an environmental factor since they will play a significant part in determining future requirements.

In terms of environmental factors, analysts must consider the possible technical advances in both offensive and defensive C3 systems. It is estimated that technological break-throughs will have the single greatest impact on our ability to sustain effective communications than all of the other environmental factors combined. I say

this because of the tremendous technical advances that have been made in both military and commercial communications and information systems over the last few years.

The complex environmental and subsystem interrelationships are exemplified in the TACS "System" Model shown in Figure 4 on the next page.

The TACS "System" Model

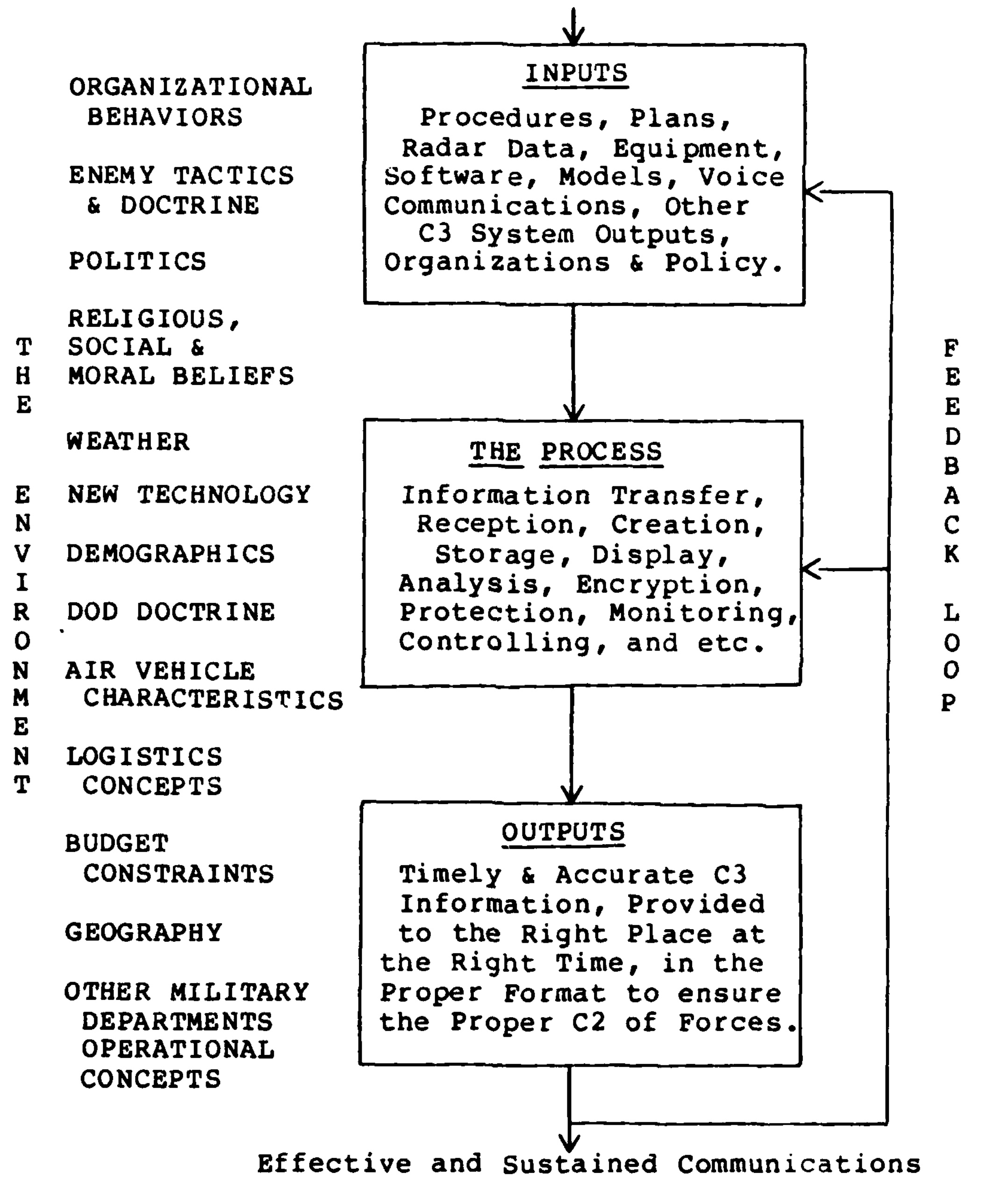

Figure 4.
The TACS System Model

Formal Applications

Included within the broad scope of systems theories there are a number of formalized approaches that the decision-maker can utilize to guide them in the decision-making efforts. In most of these instances the purpose or objective for the use of GST is to identify the complex inter-relationships that exist between the subsystems and the environment, and to reduce the complexities associated with a given decision. For example, in most cases the decision-maker establishes criteria or measures of effectiveness (MOE) in such a way as to eliminate a number of the possible alternatives (35:129-147).

As a result of a formal "systems" analysis many aspects of the suboptimization of goals problem can also be eliminated. For example, within a major C3 system there are a number of subordinate organizations, each or which has its own MOEs. Operations personnel want the flexibility to be able to communicate with the "world" from anywhere at anytime; but in reality, if such a system were available, the cost would be prohibative. The systems approach provides the decision-maker with the capability to identify and minimize conflicting goals of subordinate organizations.

In the following chapter, criteria for future C3 are identified and defined from an analysis of the operational and support concepts discussed in the AF 2000 and other related studies.

IV. Integrated C3 Criteria

> The Air Force must be honest about the limitations of technology, and it must work to give users the capability they need - survivable, secure, wartime capable systems ... (BB:47)
>
> Major General John T. Stihl, USAF
> Asst. Chief of Staff, Information Systems

I believe the primary reason our C3 systems have experienced so many problems in the past can be directly attributed to the narrow vision of our planners and the vast complexities associated with acquisition of military C3 systems. Even though "systems" theorists could logically point to the inherent complexities and uncertain environmental factors as the main cause of the problem, these factors can also be used to reduce some of the complexities associated with the selection of the "best" C3 systems. Systems theories can help us establish criteria; which, if based on totally integrated systems considerations, will reduce these uncertainties and allow our decision-makers to make more effective decisions.

The purpose of this chapter is to identify, define and establish integrated criteria for future C3 systems. These criteria can be used by planners and managers to clearly define the objectives, analyze system requirements and ultimately enable them to make more effective C3 system decisions.

In the next chapter, these criteria are combined with an application methodology that, if incorporated into the needs validation, system evaluation and acquisition phases, will increase the overall effectiveness of future tactical C3 systems.

Integrated Criteria

The following paragraphs identify and define specific C3 criteria that have been extrapolated from and integrated with the operational and logistical support concepts presented in the AF 2000 and other related studies.

Mobility

According to the AF 2000 study, mobility will be one of the most necessary attributes of our future weapons systems and support concepts. This study emphasizes that; given the potential for numerous additional technical advancements, the projected fast-paced nature of the 21st Century, and a commitment to support global force projections, mobility will be an essential feature of future weapons systems designs and support capabilities. It goes on to say that smaller units, which are more mobile and maneuverable than in the past, will be crucial for survivability in future combat situations (9:168).

In addition, the AF 2000 study emphasizes that planners should realize that future C3 systems will have to meet the challenge of rapid deployment, beddown, and re-deployment

under conditions of maneuver warfare and world wide operations (9:183).

The selection criteria "Mobility" is defined as: The quality or capability of C3 systems to move from place to place while retaining the ability to accomplish their primary mission (11:455). The following characteristics should, also, be evaluated under this criteria:

<u>Transportability</u>. The inherent capability of components or systems to be moved by towing, by self-propulsion, or by carrier via any transportation mode that is planned for the movement of the item being considered (11:713).

1. Size/weight: In terms of either mobility or transportability, it is obvious that smaller and lighter items are preferred over larger and heavier ones.

2. Mounting: Some pieces of equipment require special mounting racks or surfaces. It is preferred that these requirements be met by using standard racks or simple tie down procedures. In addition, the equipment should be able to fit into standard truck beds with or without protective coverings.

3. Packaging: Depending on the type of internal components, some individual pieces of C3 equipment require very little special packaging, while others require highly specialized packaging materials with complicated packaging procedures. Obviously, equipment having the simplest packaging requirements are preferred.

4. Modes: The more versatile the mode of transportation the better. For example, equipment that can be transported in small four wheel drive vehicles are preferred to those that require tractor-trailor rigs. Similarly, equipment that can be hand or back carried are preferred to those that require mechanized transportation modes. This is an obvious function of size and weight, but future C3 equipment may break the bulk barrier that has plagued similar systems in the past.

Set-up and Tear-down. Set-up time is the elapsed time required to put the equipment or system in operation, and is measured from the time of arrival until the equipment is operating properly. Similarly, tear-down time is the time it takes to prepare the equipment to be transported. (1:45)

Ruggedness. In order to be transportable, future C3 equipment must be rugged enough to be bounced around the country side for a few days (or months) and still be able to function properly. This characteristics should be built into the equipment and not into special packaging or handling requirements.

Power Requirements. Power requirements should be kept to the absolute minimum, and common power sources should be capable of meeting all requirements. Under this category, evaluators must also consider both start-up and normal operational power requirements. Many of our electro-mechanical equipment items require substantially higher

start-up currents and voltages than they consume under normal operating conditions.

Other. Since future wars will require these equipment to be operated from austere locations under unpredictable situations (18:11); factors such as humidity, dust, and lignt protection should not be limiting factors to the overall transportability or use of the equipment.

Flexibility

Flexible operations and support will be required to sustain combat forces across the full range of potential conflict (9:168). Systems must be designed to be able to adapt to any type of confrontation from full scale nuclear war to much lesser conflicts like the Granada invasion. Flexibility is the ability of a C3 system to meet a variety of user needs during any degree of conflict. It has been said many times that the only thing constant in the military is change! Future C3 systems must be flexible enough to meet the requirements of changing conditions and situations.

The selection criteria "Flexibility" is defined as: The ability of C3 systems to be responsive or readily adjustable to changing conditions or situations. Flexible systems or equipment are not limited in capabilities, but have the inherent ability to be able to operate successfully under a variety of conditions and situations. In addition they have the ability to expand, contract and/or reorganize in such a manner as to satisfy a wide range of user demands and requirements (1:29).

The following additional characteristics should considered under this criteria:

Expandability. This is the designed capability of the system which allows it to add enhancements without having to go through a complete or extensive modification. The ease of which the user can adapt the system to met changing requirements is the key to well planned expandability (14:220). This criterion can be best evaluated based on the design and inherent ability of the system to "grow" without causing extensive modification to the system nor resulting in extensive expenditures of funds.

Adaptability. By definition, adaptability is the level of versatility of a system in terms of its ability to change in response to changing environments (14:199). This criterion can best be evaluated based on the systems ability to sustain operations under various environmental conditions. For example, an adaptive system would be able operate under extensive enemy jamming or other MIJI conditions. MIJI stands for Meaconing, Intrusion, Jamming and Interference.

Interoperability. The capability of two or more components of equipment to perform essentially the same function or to complement each other in a system regardless of differences in technical characteristics and with negligible additional training of personnel. The ability of systems to provide services to and accept services from

other systems, units, or forces and to use the services so exchanged to enable them to operate effectively together (11:363).

Survivability

According to the AF 2000 study, this will be one of the most important characteristics needed to ensure the sustainability of our war-fighting forces. Given the high probability of a major confrontation in the next century, the recovery and reconstitution of our operational and support forces will be necessary to sustain combat operations (9:169).

Survivability of C3 systems can be related to the ability of our C3 systems to first of all withstand the initial attack, and secondly to be able to recover and reconstitute immediately thereafter.

The selection criteria "Survivability" is defined as: The measure of the degree to which C3 equipment items and system capabilities will be able to withstand either natural or man-made hostile environments without suffering abortive impairment of its ability to accomplish its designated mission (11:676). In other words, survivability is the ability of a system to continue to fulfill its minimum functions in the face of various levels of accidentally or deliberately induced damage or interference (12:3-3). The following characteristics should also be considered under this criteria:

Hardening. By definition, hardening is to make hard, i.e., to be able to withstand over-pressure of nuclear attack or other blasts (11:327). This is an important consideration, since an air burst 200 miles in the air can effectively inundate a theater of operations with Electromagnetic Pulse (EMP). Without deliberate efforts to design and shelter communications equipment against EMP, many of our systems will be destroyed.

There are, however, numerous methods available for EMP protection such as: 1) Blocking the EMP from reaching the electronic components, 2) Making the components resistant to the effects, or 3) Making the electronic systems fault tolerant - they shut down then come back-up and resume operations. In addition, planners must consider neutralizing the threat from both biological and chemical agents (7:8-10).

Redundancy. One of the most common ways to increase a system's survivability is through the procurement of redundant or back-up systems. In terms of redundant circuits, equipment or systems, the total cost and proven increased survivability must be carefully analyzed and evaluated.

For example, it is of little use to have redundant systems if the off-line system was equally vulnerable to the destructive efforts of the enemy as was the primary system. The back-up system must be able to withstand the

force that destroyed the primary system. In addition, the cost of adding redundant components or systems may not be worth the slight increase in survivability especially in dynamic situations.

Deception. This attribute can be obtained in many different ways - most of which are classified. For the purpose of this study, deception will be defined as the ability of the system to mask its operating location or signal during periods of intense conflict.

Durability. The ability to function under prescribed conditions without failing from excessive wear. For example, durability can be increased in the design phase by selecting longer-wearing material, corrosive resistant connectors and covers, and improved configuration designs. The decision of how much durability to design into C3 systems must be evaluated on an individual basis from a cost benefit analysis (16:129).

Reliability

Reliability, or dependability, is defined as the ability of a C3 system to perform under prescribed conditions as desired without excessive frequency of failures. Reliability, in engineering terms, means the probability that a system or component will not fail on any given trail or during any period of operation (16:129).

One of the most important factors to consider in this area is achieved reliability, which is a statistically valid

factor based on demonstrated measurements of performance under specific conditions and expressed at a stated confidence level (11:11).

Other factors to be considered under this criteria include operability and availability.

<u>Availability</u>. This is the percentage of the total time in which the system is fully operable. Quantitatively, availability can be defined as (1:9):

$$\text{Availability} = \frac{\text{The Mean Time Between Failure (MTBF)}}{\text{MTBF plus The Mean Down Time (MDT)}}$$

<u>Operability</u>. This is a measure of the ease at which the operator can accomplish his or her job and make the system perform according to specifications. Simple systems require a minimum amount of operator training, operator errors are infrequent, and the system can be considered user friendly. It is of little value to have a C3 system that can accomplish virtually any task if the only fully qualified operator has just been killed in action.

Maintainability

This criteria is a measure of the ease with which maintenance activities can be performed on C3 systems to keep them in top running condition (16:128). Maintainability is also a characteristic of design and installation which is expressed as the probability that an

end item or system can be restored to operational condition in a specified amount of time when maintenance actions have been performed in accordance with (IAW) prescribed procedures and resources (1:42).

Failure Rates and preventive maintenance activities should also be analyzed to ensure that the system will operate successfully over the entire time period required.

The following measures are often used by analysts as they evaluate this criteria through quantitative analysis:

1. MTBF: Mean Time Between Failure.
2. MTTR: Mean Time To Repair.
3. MTBMA: Mean Time Between Maintenance Activities.
4. MDT: Mean Down Time

Supportability. That characteristic of material which quantifies its ability to adapt to changing supply conditions and maintenance concepts (11:674). For the most part, the majority of C3 equipment items are easily supportable; however, close attention must be given to many of the associated electro-mechanical devices.

Standardization. The process of establishing by common agreement, engineering criteria, terms, principles, practices, materials, items, processes, equipment, parts, sub-assemblies, and assemblies to achieve the greatest practicable uniformity of items in supply to ensure the minimum feasible variety of such items, and to effect optimum interchangeability of equipment parts and components (11:651).

Simplicity. This is a measure of the elimination of complexities in the system design and operation. (16:127) The complexity of systems tends to increase as does the system's size, flexibility, mobility, and survivability. An effective way to measure the simplicity of a system is to evaluate the following areas:

1. Operability and Maintainability: The more complicated the operations and maintenance (O & M) activities are, the more training will have to be provided to O & M personnel. In addition, complex systems will require extensive training which will increase the training time (cost of training) and may require a larger number of maintenance technicians per system. In future wars, C3 systems may not be able to rely on the massive maintenance complexes currently in operation today (3:1-2).

2. Reproducibility: This is the ability and ease by which the C3 system, end item of equipment, or component can be consistently produced at a desired and specified quality level (16:129). Reproducible components allow for the fast reproduction of systems in times of war.

Cost

In order to evaluate this criteria thoroughly, the analyst must conduct a complete life-cycle cost effectiveness analysis. I stress "life-cycle" cost because future C3 systems must be designed to effectively operate

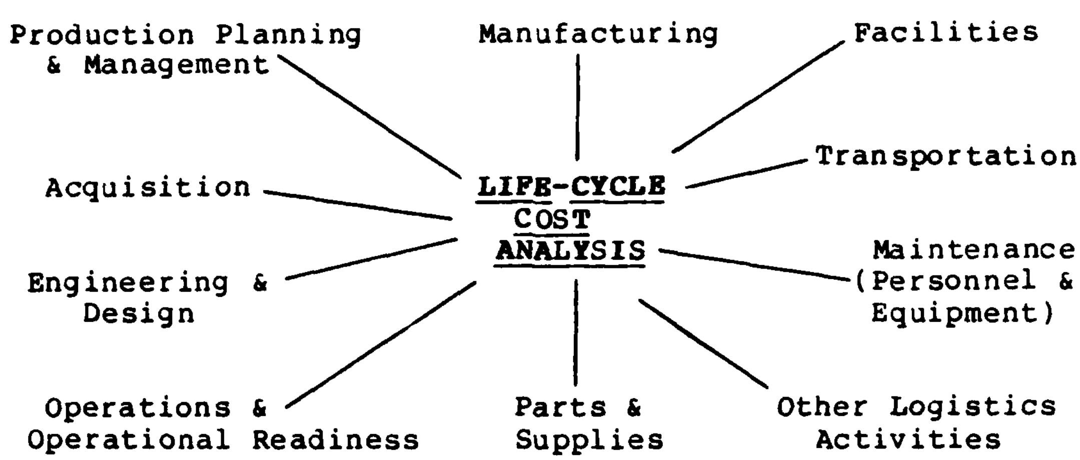

Figure 5.
Life-Cycle Cost Considerations

over many years. In addition, these costs must be related to an increase in operational capability - for a cost effective system that does not substantially increase capability is virtually worthless.

Cost analysis studies are usually completed as a type of analytical study designed to assist a decision maker in identifing a preferred choice among possible alternatives. For this reason they are often classified by types of application: 1) System Configuration or System Design Studies, 2) System Comparison Studies of already suboptimized systems, and 3) Force Structure Studies of alternative force mixes (6:3).

Some of the many aspects and considerations of life-cycle costs are as shown in Figure 5 above (4:398).

Security/Encryption.

This capability is a must for future C3 systems. The criteria "security" is defined as the ability of a system to prevent unauthorized use or disclosure of the information or introduction of false information into the system (12:3-2).

This criteria includes securing transmissions and access to our information in either physical or electrical forms. Under this criteria, the C3 system in question must meet all of the Communications Security (COMSEC) requirements necessary based on the type and classification of information being handled or processed.

In the future, literally all DOD information, and especially tactical operations information, will have to be safeguarded from enemy reception in some manner.

Additional Criteria

The AF 2000 stresses that the outcome of future conflicts will be decided primarily on the mobility, flexibility and survivability of our armed forces. In support of these three major criteria, I have established the others based on projected logistics support and basing concepts.

In addition, there are additional criteria I feel are important enough to be considered by our future C3 planners and decision-makers . These criteria have been established based on my personal experience and belief in "systems" thinking.

The following criteria have been established based on sound management practices and common sense, and should be considered equally as important as those mentioned in the AF 2000 studies.

Appropriateness

Under this criteria the systems or individual pieces of equipment are evaluated for their overall worth and ability to meet both current and projected requirements, and for their contribution to an increase in mission effectiveness. For example, if the system under consideration is ideal for the mission, but is so technically advanced that the AF would not be able to maintain it, then it would not be very appropriate.

Also, under this criteria the decision-maker must evaluate the systems contribution to the overall concept of the operation it is employed to support. By this I mean, a system that may meet all of the other criteria can still be considered unfavorable if its operation is not congruent with current AF policy or the policies of the host nation in which it would be employed. The following areas should be evaluated under this criteria:

Payoff. In order to develop a realistic evaluation payoff function for any C3 system, we must consider the overall communication system of which it is part. A basic premise is that the performance of the communications system can be improved or the cost of operation reduced by addition to or changing the current system.

Ideally, the desirable criterion is the system payoff measured in dollars and defined as the difference between the value (increased capability) and the cost (life-cycle) of the total C3 system.

The C3 system cost can be described as a function of the total communication system being evaluated, while the value can be thought of as a function of both the increased system capabilities and the resultant benefit provided to the user being served. The problem then reduces to determining the payoff for the system, i.e., the value and the cost to be determined are those that are added by the augmentation of the communications system by means of the new systems or capability (8:2-1).

Feasibility. The determination of the appropriateness of applying various techniques and/or equipment in solving a specific problem. To determine practical applications and solutions to the need or problem in question (14:221).

Responsiveness. This is the inherent ability of a system to accomplish a task in a timely manner (12:3-2).

Risk

Risk is a measure of confidence in the ability of the system to perform the assigned task or mission as stated or specified. The selection of a C3 system based on proven technology would be to assume little risk; however, in order to incorporate advanced technology into a vital C3 system would be to assume a great deal of risk.

According to the AF 2000 study, technological exploitation will be essential for weapons systems reliability, maintainability, and suitability (9:183); however, the decision-maker must realize that as the technical exploitation increases so do the risks.

Criteria for Future C3 Systems

In terms of the general criteria, there is not much difference between tactical or strategic C3 system (with the exception of mobility), nor is there a significant difference between the criteria for current or future C3 systems. For this reason, I feel confident that these criteria could be used in virtually any C3 decision-making scenario.

Our military planners should make more effective decisions if they evaluate the alternatives based on the following criteria:

CRITERIA FOR FUTURE C3 SYSTEMS

1. MOBILITY
2. FLEXIBILITY
3. SURVIVABILITY
4. RELIABILITY
5. MAINTAINABILITY
6. COST
7. SECURITY
8. APPROPRIATENESS
9. RISK

Figure 6.
Criteria for Future C3 Systems

V. Multiple Criteria Problem Solving

> We in AFLC are in an information systems revolution, as is most of the world. It may ultimately be as significant as the industrial revolution. (31:4)
>
> General Earl T. O'Loughlin, 1986
> Commander Air Force Logistics Command

In the case of analyzing and selecting C3 systems capable of meeting the challenges of the future, the decision-maker is faced with a highly complex problem and must attempt to select the best alternative from a list of ever increasing possibilities. This is a common problem faced by managers and decision-makers who must attempt to choose the best or optimal course of action among a number of feasible alternatives.

There is disagreement, however, as to what constitutes the "best" solution and that is were the intuition and judgment of the decision-maker becomes a vital element in solving multiple criteria based problems.

In these types of decision problems there is no objective function, as used by operations research or management science specialists, that can adequately serve to compare the differences in desirability among the possible/feasible courses of action. Multiple criteria problem solving is a method that can deal with these types of problems (33:133).

Multiple criteria problem solving could also be called multiobjective or multiattribute decision-making. The difference, however, is not significant enough for me to elaborate on in this research effort. It is, however, important to understand the concept and application of these methodologies as they relate to GST and the establishment of integrated criteria.

The important quality of this decision theory is that it takes into account both the quantitative and qualitative aspects of decision theory. This methodology allows the decision-maker to apply a wide range of either satisficing or optimizing techniques in the problem solving effort. For example, there are a number of totally subjective common sense approaches that can be used, or the decision-maker may choose to use any of a number of the more objective quantitative approaches (33:133-136).

In this section, one of the most widely used approaches to solving multiple criteria problems is discussed, and a number of the more quantitative multiobjective optimization methods are mentioned. The following sections further clarify the applicability of this problem solving methodology and thoroughly explain one of the common sense approaches called the "Score Card" method (20).

In addition, a practical example and evaluation of three types of transmission media (communications links) is provided to serve as relatively a realistic application of this problem solving technique.

Multiple Criteria Problems

As in the case of selecting future C3 systems capable of meeting projected requirements, many decision situations are characterized by multiple objectives, criteria or goals rather than by a single objective. These objectives may be complementary or (which is usually the case) they are conflicting and incommensurate to various degrees. In these instances the decision-maker is unable to rely on linear programming, operations research or management science methodology to solve the problem.

For this reason many multiobjective problem solving techniques have emerged over the past decade or so. Most of these methods require the decision-maker to provide either his or her intuitive judgment in determining a solution, so that some of the complexities are removed and the non-programmable portions of the problem can be solved by either a math or computer simulation function (32:76; 33:133). One of the easier methods to solve these types of problems is by using score cards to evaluate each of the possible alternatives.

Score Card Methodology

The "score card" methodology is a formalized, common sense problem solving technique designed to reduce the complexities associated with a given decision. It is especially beneficial when being used to distinguish between

alternatives that must be evaluated based primarily on the decision-makers perception, experience or judgment.

A quick and effective way to display the results of a complicated comparative analysis can be accomplished by using the score card method. The findings of the analysis are consolidated onto a single page graphic, like a transparency or hard page copy, and the "scores" are presented in a matrix form corresponding to both the criteria in question and the particular system being evaluated. In addition, the results can be displayed on the score cards by using an unlimited number of graphics, colors or numbers.

One method is to rate or "score" each of the criteria by using symbols or colors. The resultant score (symbol or color) would depict how well the system being evaluated measured up to either a set of established standards or some another comparable system. A perfect example of this methodology is that used by Consumer Reports magazine. This magazine will often compare homogeneous products and rate them on a good, better or best basis. In this case symbols are used to quickly and simply display the results of the analysis (20).

A second method is to rate or "score" each of the criteria based on some cardinal value, where the best ratings are either very high or low depending on the situation. For example, a system that does not adequately meet a certain criteria could be given a zero in that area, and

conversely the same system could be given a ten (the maximum rating) under another criteria. Each of these methods is further defined in the following paragraphs.

The Symbolic Score Card. When using this method the analyst rates the system or equipment under evaluation against some subjective measure and assigns each criteria a symbolic rating. For example, the analyst may chose the symbol "□" to represent a good rating, the symbol "◪" for a better rating, and the symbol "■" would indicate the best possible rating of the alternatives being evaluated. More realistically, it is easier to use color schemes to more dramatically display the results of an analysis.

In the practical example, discussed later in this section, the symbols shown above are used to graphically depict the results of an analysis. I strongly suggest, however, that colors also be used along with the symbols to more dramatically display the results.

Colors such as red, yellow and green can be used to indicate the degree to which each of the systems being evaluated measured up against the established criteria. A "red" rating, for example, could indicate that the system was deficient in that particular area, and reflects the lowest possible rating. A "yellow" rating would depict an average rating, or that the system is not as good as some of the others and could be improved. A "green" rating could be the top rating and indicate that the system meets all of the requirements under that particular criteria (20).

	CRITERIA	TRANSMISSION MEDIA Tropo	Satellite	Land Lines
1.	MOBILITY	■	◪	□
2.	FLEXIBILITY	■	◪	□
3.	SURVIVABILITY	◪	□	■
4.	RELIABILITY	◪	◪	■
5.	MAINTAINABILITY	◪	◪	■
6.	COST	◪	□	■
7.	SECURITY	◪	◪	◪
8.	APPROPRIATENESS	◪	■	□
9.	RISK	◪	□	■

Figure 7.
A Score Card for Communication Links

An example of a symbolic score card is illustrated in Figure 7 above. This figure is used to illustrate the presentation of the reults of an analysis concerning transmission media that could be used in the CER.

A detailed explanation of the rational for the ratings is included in Appendix A, Analysis and Results of Evaluation. In this appendix, I have provided a brief synopsis of the findings and reasons for each of the individual ratings as they might be presented in an Executive Summary. It is interesting to note at this time, however, that in order to achieve the highest possible rating (or measure of effectiveness) all three systems would be required.

Cardinal Score Cards. This method allows the analyst to assign a numeric value (the score) for each of the criteria to the system being evaluated based on the findings. The scores are then simply summed and the alternative with the maximum value is selected. The analyst could score each of the systems on a scale of say 1 to 10 or virtually any number so long as the scale is constantly and equitably used for all of the criteria and all of the systems being evaluated.

The best alternative solution can be identified by solving the following single objective function (33:136):

$$\max \quad \Sigma_i \; W_i \; F_i(x) \text{ such that } x \in X$$

The "weight," Wi, in the following examples is a constant value (the number one), but could vary among the criteria depending on the analyst or the situation (33:136). Weighting is very important in this technique because the summed totals of the ratings are often a dominant factor in the final decision. This is not necessarily the case, especially when the individual ratings have not been established or awarded using a common methodology.

In the following examples used in this section, a scale of 1 to 5 has been selected, with one being the lowest possible value and five being the highest. A score of five would indicate that the system significantly exceeds the

criteria requirements in question. A score of one on any of the criteria would indicate that the system in question barely meets minimum requirements. A score of zero in any of the criteria evaluation blocks would eliminate the system from any further consideration; however, this situation is not depicted in any of the examples.

For example, suppose you had to decide between two mini-computer systems to be installed in each of the ASOCs. The resultant score card could look something like that shown in Figure 8 below.

		MINI-COMPUTERS	
	CRITERIA	AZ-1110	B-2500
1.	MOBILITY	3	2
2.	FLEXIBILITY	4	4
3.	SURVIVABILITY	3	4
4.	RELIABILITY	3	4
5.	MAINTAINABILITY	2	4
6.	COST	2	3
7.	SECURITY	4	5
8.	APPROPRIATENESS	4	4
9.	RISK	4	2
	TOTALS	29	32

Figure 8.
A Cardinal Number Score Card

Both of these score card methodologies can be used to evaluate either general C3 systems or specific equipment or system capabilities.

In addition, these systems could be re-evaluated based on the type or level of warfare expected. For example, satellite communications might score significantly higher in a theater conventional war in the vast regions of South America simply because these nations currently do not have the ability to detect and destroy satellites like the Warsaw Pact nations.

Limitations

There are, however, a number of problems and limitations associated with this methodology which must be mentioned. First of all, many analysts would argue that the scores are too subjective and could vary significantly between evaluators. Secondly, the score card method-ology does not differentiate the marginal utility of each of the criteria (33:147).

By this I mean, it is difficult to evaluate the marginal utility of a satellite system's appropriateness against the high mobility of troposcatter radio. For this reason, dominance of a system can not be established without correcting this major limitation. One method that attempts to correct this later deficiency is called the Implicit Utility Function.

Other Methodologies

The purpose of this thesis is not to suggest that the score card methodology is the best or only way to solve multiobjective optimization problems, and for this reason I feel compelled to briefly explain some of the more noteworthy methods that have also been used successfully in this area.

Targets or Ideals. This is another common sense approach. Here the decision-maker sets target values for all of the objective functions (criteria in our case), and the achievement of each target is established as a constraint. Targets can be set in many ways. For example, one extreme is to set them as the minimal values with which the decision-maker feels satisfied, or they could be set to the "ideal" level which is its best or highest possible value when all other criteria are ignored. Target setting is usually an iterative process with adjustments being made after each iteration (33:136-137).

Efficiency. This is another common sense approach, where it is assumed that the decision-maker's satisfaction will never decrease, i.e., more is always better. Sometimes, because the set of efficient solutions is extremely large, researchers have suggested that only partial sets of the efficient solutions be generated. In these cases, the decision-maker is required to define a series of weights and targets, and from these constraints only a sub-set of the possible efficient solutions is generated.

The decision-maker repeats this process, after changing the weights and targets, and eventually the compromise solution is selected. The compromise solution is the one in which the maximum deviations from the ideal are minimized (33:138-142).

Explicit Utility Maximization. This methodology combines the fields of multiple objective mathematical programming and multiple attribute utility theory. The advantage of this approach is that it uses the vast body of existing single-objective theory, knowledge, algorithms, software, and experience and makes them readily available for solving multiobjective optimization problems (33:144-147).

Summary

In order for the AF to meet requirements for future tactical C3 systems, it must constantly evaluate and re-evaluate its operational C3 systems from a systems perspective, and firm criteria must be established as the basis for system evaluation and selection.

These criteria should be integrated with both the operational and logistics support concepts stated by our military leaders. This philosophy will help establish a new era of C3 needs identification, validation, selection and operation. All of which should lead to greater effectiveness in the world of future tactical C3 system operations.

VI. Conclusion

> Without communications - the only thing I can command is my desk! (47:B)
>
> General Curtis E. LeMay, 1952
> General Thomas Power, 1965
> General Lew Allen, 1978
> *et al*

General

The intention of this research effort was to develop and explain how the AF could increase its effectiveness in selecting future C3 systems. It is this researcher's opinion that in order for a C3 system to be effective it must first of all be used continuously, and secondly it must be able to provide our commanders with multiple, survivable C3 channels during war or other similar situations.

At first glance, one might think it unreasonable to judge the effectiveness of a C3 system based on its use, but far too often in my career I have seen C3 systems lay idle simply because it was easier and quicker to use the commercial communication systems than the military C3 system in question. Daily use of C3 systems is a must if they are going to be effectively operated during contingencies or even higher level conflicts. It is important to realize however, that the effective and daily use of peace-time C3 systems does not necessarily guaranty that they will be able to provide sustained communications during contingencies.

Our future C3 systems must be tested and operated in realistic war-like exercises. This is the only way, short of going to war, that these systems can be effectively evaluated. It has been my experience that C3 inputs to major exercises have been down-played by both the inspection teams and the plan implementors.

During base-wide simulated communications outages, most base agencies will continue to use their telephones and a half-hearted effort is made to implement the communications isolation plan. In most instances only the Command Post or Center is truly evaluated. I have often wondered how long a base could sustain operations without its peace-time communications systems. Future C3 systems must be able to overcome the pitfalls and problems encountered in the past. This objective can be accomplished only by the coordinated effort of all concerned parties.

Results

In order to accomplish the objective of this research effort, I concentrated on developing both a conceptual framework and a problem solving process for evaluating and selecting future tactical C3 systems. To establish a basis for comparison and analysis, I discussed one of the most complicated C3 systems operating in the world today - the TACS in the CER.

From this basis I established a need to view (from a conceptual stand-point) complicated C3 systems from the

"systems" perspective. The concept is that, in order to be effective, these systems must be integrated with and based on projected operational and logistics support policy. The AF 2000 and other related studies were used to hypothetically project future C3 requirements.

The end result of this analysis was a list of nine criteria by which both current and future C3 systems could be evaluated. These criteria were validated as referents in the AF 2000 studies and through interviews with both operations and logistics experts.

These criteria were subsequently matched with a multiple criteria problem solving methodology - called the "Score Card." The score card methodology was selected because it is a commonly used and formalized multiple criteria problem solving process, and because it allows the analyst various degrees of latitude in the evaluation and rating procedures. In addition, the results of the evaluation can be well documented and displayed in a simple yet comprehensive manner.

The combination of the "Systems Approach" concept and the "Score Card" problem solving methodology is extremely appropriate when attempting to solve dynamic and complex C3 problems. This concept and process will provide our C3 managers, users, planners and evaluators with a flexible and necessary problem solving tool that, if used, will increase the effectiveness of our future C3 systems.

This thesis does not claim to have solved the future problems of C3, but it does stress the need for our current C3 decision-makers to start making more effective decisions.

As alluded to in the AF 2000 study, the search for better C3 systems and evaluation methods must never cease -

> The Air Force must, therefore, make it its business to deal continuously with the uncertainties of the future instead of intermittently forecasting things to come. The future is not preordained and logical solutions are not self-evident! (1:2)

Recommendations For Further Research

This thesis only scratches the surface of the research that needs to be accomplished if we are to provide sustained and effective C3 systems to our operational and support commands. In regards to this research effort, further research is needed to validate the true effectiveness of both the proposed methodology and criteria.

The methodology suggested should be evaluated through empirical testing and actual application to ensure its effectiveness, reliability and applicability. This analysis can be accomplished in many ways, but the most obvious approach would be to apply this method to past situations and compare the resultant decisions. If this method is superior to those of the past, then the results should differ.

For example, a few years ago the decision was made to install secure telephones in the offices of key personnel

throughout the AF. Logically and intuitively this action sounds like a good decision, but the true effectiveness of this decision has not been determined. The entire analysis, evaluation and selection decision-making process could be re-constructed using this methodology. The end result would be a comparative analysis between the two decision-making methods to determine the resultant differences (if any) and the overall effectiveness of the actual versus hypothetical solutions.

As for the criteria, further research is required to validate their comprehensiveness, definition, range of application and appropriateness. In addition, each of the individual criteria must be tailored to meet a variety of user needs, and methods must be developed that will enable analysts to use these criteria to rate or score systems without bias or any other limiting factor.

Summary

Because of the uncertainties and complexities in the world today, future C3 systems will have to be more mobile, survivable, flexible, reliable, maintainable, secure, cost effective, appropriate and less risky than in the past. Unless future C3 subsystems are integrated with the "systems" they support, I believe that our C3 systems will continue to experience past problems.

If we are to meet the challenges of the future, our current planners and decision-makers must start making more

effective decisions today concerning tomorrows C3 systems.I believe an important first step in this direction is to make our commanders realize the true limitations of our current C3 systems. Once this has been accomplished, changes to our current C3 systems could be initiated using new and better problem solving techniques.

The future ability of our C3 systems to meet the demands of both combat (operational flying units) and combat support organizations (logistics, civil engineering, supply, etc.) can not rest solely on the shoulders of our "communications" officers, but must be shared equally by the user.

I say this because, in the past, the "user" has been able to easily justify and validate requirements for new C3 systems based on advanced technology and we communicators have installed these new, state-of-the-art and highly technical C3 systems all over the world.

The "Systems" perspective should prevent these problems from occurring, and sound management practices should keep them from happening in the future. The leaders in the AF along with the C3 specialists in AFCC have the managerial, analytical and technical skills necessary to field war-time capable and effective C3 systems if they all work together in an integrated effort.

Appendix A: Analysis Report on Transmission Media: An Executive Summary

Background

One of the most critical aspect in establishing an effective C3 capability is determining the most appropriate and effective mode of transmission (the communications link) to be used in-conjunction with the system.

To illustrate this methodology, a comparative analysis using three of the most frequently used transmission modes was conducted, and the following military equipments were analyzed: 1) Relay- less radio using the AN/TRC-97 mobile single side band troposcatter radio, 2) Relayed radio using the AN/TSC-94 supper high frequency satellite terminal using a line-of-sight (LOS) transeiver, and 3) Physical conductors using the telephone lines supplied by the German Telephone System (Duetches Bundespost) (38:63).

These modes were selected for evaluation because each of them were able to meet the following minimum requirements: 1) transmit and receive information up to 150 miles, 2) transmit secure (encrypted) information, 3) access other NATO and USAFE C3 systems, and 4) be able to accommodate multiple users with a minimum of 12 circuits (four data and eight voice).

These systems were evaluated against the following criteria using the "Score Card" multiple criteria problem

solving technique: 1) Mobility, 2) Flexibility, 3) Survivability, 4) Reliability, 5) Maintainability, 6) Cost, 7) Security, 8) Appropriateness, and 9) Risk.

The evaluation results, discussed below, have been condensed to include only the most significant advantages or limitations found during the analysis.

Results of Analysis

The analysis results (expressed in terms of the individual criteria) are as follows:

1. Mobility: The troposcatter radio, hereafter called the Beyond the Line-of-Sight (BLOS) radio, was found to be the most advantageous because it was the fast and easy to set-up, extremely rugged, and scored well on all of the other considerations. The satellite terminal was rated lower because it experienced difficulty traveling over rough terrain and took much longer to set-up. The mobility of the German Telephone System, hereafter referred to as "land lines," was restricted by the location of previously installed cable which was considered a severe limitation.

2. Flexibility: Both the BLOS radio and the satellite terminal were found to be extremely flexible; however, the adaptability of the BLOS radio system gave it a clear advantage. The BLOS radio has a much wider frequency range, was interoperable with numerous other systems and was the easiest to expand to accommodate more users should the need

arise. The satellite terminal was limited by the number of channels it could (or would) be authorized, and it had a very narrow operational frequency range. In addition, the requirement for a compatible receive station severely limited the flexibility of this system. The land line system was severely limited since land lines could not readily adapt or be changed to new locations should contingencies arise.

3. <u>Survivability</u>. This was the hardest area to evaluate because so much depended on the type and level of conflict being considered. The results of studies in this area have shed little light on the true effects modern warfare will have on transmission media, but overall the BLOS radio system emerged as the most survivable over the full range of possible conflicts. The satellite system was considered to be extremely limited because of the vulnerability of the satellite itself and because they are easily jammed. The land line system was rated very high in low level conflicts, but its ability to function function properly in a nuclear environment was questionable.

4. <u>Reliability</u>. In this area, the media with the highest availability was the land lines. The reliability other transmission modes was limited by both the number of maintenance actions (failures and preventative) and environmental effects on radio waves. However, both the BLOS radio and the satellite terminal published availability

rates of around 99%, which increased their overall rating in this area. The BLOS radio was rated the higher of the two, because the complexities associated with maintenance and repair of the satellite terminal required significantly longer down times. This was considered a major limiting factor (45:19, 37:2-140).

5. Maintainability. Again the land lines were found to be superior in this area; however, the BLOS radio system was found to be the easiest system to maintain. The satellite system had significant problems in this area - again the complexities of the systems required an excessive amount of maintenance activities. The mean time between failure (MTBF) for the BLOS radio is approximately 800 hours ((45:36), while the satellite terminal's MTBF is approximately 110 hours (37:1-139 to 2-140).

6. Cost. Land lines were rated superior in this area, however it must be noted that this rating was based on the cost of 12 circuits. If land lines had to be available at every location operable by the other two systems, the cost differential would narrow considerably. The life-cycle cost of the BLOS radio system has been estimated to be considerably lower than that of the satellite terminal.

7. Security. Since all of the modes could be encrypted utilizing basically the same crypto equipment, none of the systems was rated significantly deficient. It must be mentioned, however, that the land line system is the

only media that allows for end-to-end encryption. But the cost of installing and maintaining 24 (one at each end) crypto units would not be cost effective for a mobile system.

8. Appropriateness. For the first time, the satellite system was found to be the most appropriate, i.e., it is the one with the biggest payoff in increased capability amd effectiveness. The ability of a system to connect users to literally anyone, anywhere in the world is very appropriate in the tactical arena. But, on the other hand, the BLOS system has proven its ability to sustain effective communications during various levels of conflict and; therefore, has been rated equally as appropriate. The use of land lines in a highly mobile environment was considered inappropriate.

9. Risk. The ability of land lines to effectively transmit and receive communications traffic has been well established over the years, and therefore this mode was given the highest rating. Satellite terminals were rated as extremely risky due to the complexities and lack of proven effectiveness in actual combat situations. And, BLOS radios were rated very high based on based on the effectiveness and reliability of BLOS systems over the years.

It must be noted at this time, that none of the systems evaluated could be considered totally effective, nor does anyone system meet all of the established criteria.

Recommendations

In an effort to substantially increase the effectiveness of our C3 systems in this region, the beneficial aspects of each one of the specific transmission modes must be made available to our operational commanders. As a result of this analysis, a mixture of transmission modes is recommended. Only through a combination of transmission modes can we realistically support and plan for multiple levels of conflict.

Our first priority should be establish an effective BLOS radio relay system throughout the CER. After this system has been proven effective, it should be augmented with a number of satellite terminals. These terminals should be designed to support, not replace, the BLOS radio relay system. Finally, land lines should be installed at a number of pre-planned locations throughout theater. The number and location of the land lines could be determined from our current war planning documents. The land lines should only be used in contingencies (the last resort), but should be tested frequently.

Each of these transmission modes should be strategically operated and located to take full advantage of their most beneficial aspects. The goal is to provide effective and sustained C3 systems - not redundant capabilities.

Note: This appendix has been developed to serve as a conceptual guide to the application of the "Score Card" methodology discussed in Chapter 6. The results of the analysis were not based on any formal study, and are not to be considered factual. The results of this analysis should not be used in any other context, i.e., other than the one presented in this document.

Appendix B: List of Acronyms

Acronym	Meaning
A/C	Aircraft
AAFCE	Allied Air Forces Central Europe
ACCHAN	Allied Command Channel
ACE	Allied Command Europe
ACLANT	Allied Command Atlantic
AD	Air Defense
ADP	Automatic Data Processing
ADPE	Automatic Data Processing Equipment
AF	Air Force
AFB	Air Force Base
AFR	Air Force Regulation
ATO	Air Tasking Order (FRAG)
AFCC	Air Force Communications Command
AFCENT	Allied Forces Central Europe
ASOC	Allied Support Operations Center
ATAF	Allied Tactical Air Force
ATC	Air Traffic Control
ATOC	Allied Tactical Operations Center
AUTODIN	Automatic Digital Network
AUTOSEVOCOM	Automatic Secure Voice Communications
AUTOVON	Automatic Voice Network
AWACS	Airborne Early Warning and Control System
C2	Command and Control
C3	Command, Control and Communications
C3I	Command, Control, Comm. and Intelligence
C-E	Communications-Electronics
CAS	Close Air Support
CBT	Combat Plans Division
CCT	Combat Control Team
CER	Central European Region
CINC	Commander-in-Chief
COMM	Communications
COMMSEC	Communications Security
COMTAF	Commander Tactical Air Forces
CRC	Control and Reporting Center
COB	Collocated Operating Base
BLOS	Beyond the Line-of-Sight
DCA	Defense Communications Agency
DCS	Defense Communications Service
DEFCON	Defense Readiness Condition
DL	Data Link
DOD	Department of Defense
DOL	Dispersed Operating Location
DTE	Data Terminal Equipment

ECCM	Electronic Counter-Countermeasures
ECM	Electronic Countermeasures
EMP	Electromagnetic Pulse
ETRO	Estimated Time of Recovery
ETS	European Telephone System
FAC	Forward Air Controller
FACP	Forward Air Control Post
FEBA	Forward Edge of the Battle Area
FOL	Forward Operating Location
FRAG	Fragmentary Order (same as ATO)
FRG	Federal Republic of Germany
FY	Fiscal Year
GMT	Greenwich Mean Time
GPS	Global Positioning System
GST	General Systems Theory
HF	High Frequency
I/O	Input/Output
IAW	In accordance with
ID	Identification
IFF	Identification Friend or Foe
ILS	Integrated Logistics Support
IS	Information Systems
ISS	Information Systems Squadron
JCS	Joint Chiefs of Staff
JOC	Joint Operations Center
JTF	Joint Task Force
LCC	Life Cycle Cost
LOS	Line-of-Sight
MEI	Management Effectiveness Inspection
MIJI	Meaconing, Intrusion, Jamming and Interference
MOB	Main Operating Base
MOC	Modular Operations Center
MPC	Message Processing Center
MTBF	Mean Time Between Failures
MTBMA	Meantime Between Maintenance Action
MTTR	Mean Time To Repair
NAF	Numbered Air Force
NADGE	NATO Air Defense Ground Environment
NATO	North Atlantic Treaty Organization
OB	Order of Battle
OPLAN	Operations Plan
OPORD	Operations Order
OPS	Operations

OR	Operational Ready
ORI	Operational Readiness Inspection
RECCE	Reconnaissance
RFI	Radio Frequency Interference
RX	Receive or Receiver
SATCOM	Satellite Communications
SAWS	Survivable ATOC/Wing Switch
SOC	Sector Operations Center
Sq	Squadron
SqOC	Squadron Operations Center
STOL	Short Takeoff and Landing
TAB	Tactical Air Base
TAC	Tactical Air Command
TACAIR	Tactical Air
TACR	Tactical Air Command Regulation
TACS	Tactical Air Control System
TACP	Tactical Air Control Party
TAF	Tactical Air Forces
TAFIIS	Tactical Air Forces Integrated Information System
TCG	Tactical Control Group
TCW	Tactical Control Wing
TX	Transmit or Transmitter
TX/RX	Transmit/Receive
TROPO	Tropospheric Scatter
UHF	Ultra High Frequency
U.S.	United States
USAF	United States Air Force
USAFE	U. S. Air Forces Europe
VF	Voice Frequency
VTOL	Vertical Takeoff and Landing
WOC	Wing Operations Center
WX	Weather

Appendix C: Glossary of Terms

Air Operations Center* - An operations facility that provides a means for Tactical Air Force Commander to exercise centralized control over the forces.

AUTODIN** - A worldwide automatic communications system which provides message-switched data service for the Department of Defense. It is part of the Defense Communications System (DCS).

AUTOVON** - A worldwide automatic communications system for end-to-end circuit-switched voice connections for the Department of Defense and certain non-DOD agencies. (Part of the DCS)

Automatic Data Processing* - Data processing performed by a system of electronic or electrical machines so interconnected and interacting as to reduce to a minimum the need for human assistance or intervention.

Automatic Data Processing Equipment* - General purpose commercially available, automatic data processing components, and the equipment configurations created from them, regardless of use, size, capacity, or price that are designed to be applied to the solution or processing of a variety of problems or applications, and that are not specially designed as opposed to configured, for any specific applications.

Bare Base* - A base having a runway, taxiways, and parking area which are adequate for the deployed force and possessing an adequate source of water that can be made potable.

Channel** - The smallest subdivision of a carrier system by which a single type of communications service is provided; for instance, a voice channel, data channel or a teletype channel.

Collocated Operating Base - An major allied installation or main operating base, designated as a location to serve deployed tactical aircraft. A term used mostly in the European Theatre.

Command and Control (C2) - The exercise of authority and direction by a designated commander over assigned forces in the accomplishment of the mission.

Command, Control and Communications (C3) - Those communications and data automation personnel, facilities, systems and equipments designated to provide the designated commander with the electrical and electro-mechanical information systems by which Command and Control functions are accomplished.

Common-user Communications* - Voice and record communications systems, networks and facilities established and operated to server the general needs of the Department of Defense for electrical exchange of common categories of information. For example; AUTODIN, AUTOVON, and AUTOSEVOCOM.

Data Automation* - The use of electronic or electro-mechanical equipment and associated techniques to automatically record, communicate, and process data and to present the resultant information.

Data Processing* - The preparation of source media which contain data or basic elements of information, and the handling of such data according to precise rules of procedure to accomplish such operations as classifying, sorting, calculating, summarizing, displaying, and recording.

Dispersed Operating Base/Location - A U.S. military base or location that is equipped, manned and maintained in a reduced operational status with the capacity to expand operations on short notice.

Employment* - The tactical use of aircraft in a desired area of operation.

Information System - Any electronic or electro-mechanical communication, telecommunication, voice or record, automatic data processing, computer, software or hardware, or air traffic control system. Information Systems is the generic term used to identify those organizations and resources that have been merged from the old Data Automation and Communications organizations.

Interoperability - The ability of systems or organizations to exchange information or services directly between themselves and their users.

Logistics and Administrative Support* - Includes those aspects of operations which deal with: a) research, development, test and evaluation; b) acquisition, storage, movement, distribution, maintenance, evacuation, and disposal of material; c) movement and

evacuation of personnel; d) medical services; e) communications services; f) acquisition or construction, maintenance, operation and disposition of facilities; g) other logistics and administrative services to include planning, management, and execution of responsibilities.

Main Operating Base - A major AF installation that is equipped, manned and maintained in a full state of operational readiness.

Management Information System - An integrated, user machine system for providing information to support operations, management and decision making functions within an organization.

Operational Concept* - A statement about intended employment of forces that provides guidance for posturing and supporting combat forces.

Survivability* - The capability of a system to withstand a man-made hostile environment without suffering an abortive impairment of its ability to accomplish its designated mission.

System* - A composite of equipment, skills, and techniques capable of performing and/or supporting an operational role. A complete system includes related facilities, equipment, material, services, and personnel required for its sustained operation in its intended environment.

Tactical Air Control System* - The organization and equipment necessary to plan, direct, and control tactical air operations and to coordinate air operations within other services.

Telecommunications** - Any transmission or reception of signals, signs, writing, images, and sounds or intelligence of any nature by wire, radio, visual, or other electromagnetic media.

Transmission Media - The particular method and/or equipment used to transfer information or data between locations.

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This thesis describes a conceptual and methodological guide by which managers and planners can evaluate (by comparative analysis) and select future Command and Control, Communication systems. The general issue is that technological advances have rendered the world of C3 confused and in need of new problem solving methodologies.

The concept is, that in order for future tactical C3 systems to become more effective, they must be integrated with projected operations and support considerations. This integration can best be accomplished by viewing the C3 system in question from a "Systems" perspective. The systems approach identifies the complex interrelationships between C3 systems, the users and the operational context in which the system is to function. The result is a list (score card) of integrated criteria by which future tactical C3 systems can be evaluated.

The methodology discussed combines the flexibility and broad scope of General Systems Theory with the simplicity of the "Score Card" multiple criteria problem solving technique. Several score card applications are discussed.

Future C3 systems can be analyzed, evaluated and selected by using this conceptual and methodological guide.

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